

# MULTI-FREQUENCY INVESTIGATION INTO SCATTERING FROM VEGETATION OVER THE GROWTH CYCLE

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## ABSTRACT

In this investigation, we aim to collect and use time-series multi-frequency microwave data over winter wheat during entire growth cycle to characterize vegetation dynamics and to quantify its effects on soil moisture retrievals. We plan to incorporate C-band radar and VHF receiver within the existing L-band radar/radiometer system called ComRAD (SMAP's ground based simulator). With C-band's ability to sense vegetation details and VHF's root-zone soil moisture within ComRAD's footprint, we will be able to test our 'discrete scatterer' vegetation models and parameters at various surface conditions. The purpose of this study is to determine optical depth and effective scattering albedo of vegetation of a given type (i.e. winter wheat) at various stages of growth that are need to refine soil moisture retrieval algorithms being developed for the SMAP mission.

**Index Terms**— One, two, three, four, five

## 1. INTRODUCTION

Sensing vegetation biomass and underlying soil moisture is valuable to improved understanding of the Earth's water, energy, and carbon cycles, and to many applications of societal benefit. Microwave sensors are well suited for this due to their high sensitivity to land biological and hydrological features. However, retrieving biophysical parameters of interest from microwave measurements is a highly difficult task due to the complexity of microwave interactions with Earth. For example, vegetation poses a challenge for soil moisture retrieval since the emission from soil is attenuated and scattered by the vegetation while the vegetation contributes its own emission. Similarly, variations in underlying soil moisture makes retrieval of biomass a challenging task since both the soil surface and vegetation canopy contribute together to the observed brightness temperature.

Appropriate corrections for biomass must be made in order to make reliable soil moisture estimation. In a similar



Figure 1: ComRAD instrument system..

manner, appropriate corrections for soil moisture are needed to make reliable biomass estimation. Concurrent multi-frequency observations can be an opportunity to investigate contributions emerging from different layers of vegetation and soil. Penetration depth into vegetation and soil is directly related to frequency. Longer wavelengths (i.e. P-

band) penetrate deeper into vegetation and soil, while higher frequencies (i.e. C-band) are more sensitive to volume scattering within vegetation and can provide information on upper layer of vegetation.

To extend NASA's existing ComRAD instrument system (L-band radar/radiometer)'s sensing capabilities within both vegetation and soil, C-band radar and VHF receiver are currently being integrated. With the upgraded system, we will collect coincident multi-frequency (L-band active/passive, VHF bistatic and C-band active) data sets at the SMAP's incidence angle (40°) in time series over a long enough time period to reflect changing surface conditions (vegetation, soil moisture, etc.).

In this study, we will present our preliminary results about effect of changing vegetation (i.e., growing winter wheat) on vegetation parameterization (effective scattering albedo [1] and opacity) in passive L-band soil moisture retrievals. In particular, C-band radar will be used a tool to help determine the attenuation and scattering properties of the vegetation [2] while VHF receiver will be used to validate the root zone and surface soil moisture retrievals [3]. In addition, the experiment will provide us a data set to investigate empirical relationships between vegetation properties at various frequencies so that future and current satellite missions with different frequencies can be more effectively utilized in an integrated fashion.

## 2. COMRAD INSTRUMENT SYSTEM

The ComRAD (for Combined Radar / Radiometer system) microwave instrument system used in this investigation has been developed jointly by NASA/GSFC and George Washington University. It has been recently undergrounding several upgrades to be able to collect concurrent multi-frequency observations to investigate different layers of vegetation and soil.

### 2.1. Current System

Current ComRAD includes a dual-pol 1.4 GHz radiometer and a quad-pol 1.24-1.34 GHz radar sharing a new 1.22-m Cassegrain parabolic dish antenna and subreflector to achieve a very low loss system. Absolute accuracy and the sensitivity of the instrument are  $\pm 1$  K and  $\pm 0.1$  K, respectively. External calibration is achieved using cold sky and ambient microwave absorber targets for the radiometer, and flat plates and dihedral reflectors for the radar. When deployed in the field, ComRAD is mounted on a 19-m hydraulic boom truck (Fig. 1) and can operate over a range of incidence angles from 0° to 175° and a 300° range in azimuth. The mounting platform can also accommodate additional small instruments such as a CropScan visible/infrared sensor for vegetation reflectance measurements and a thermal infrared sensor for scene physical temperature.

### 2.2. System Upgrades

C-band radar and VHF receiver are currently being incorporated into the existing ComRAD system to extend its sensing capabilities within both vegetation and soil. The C-band radar system will use a separate horn antenna but be configured around the same vector network analyzer that is currently used for L-band radar. The C-band radar will operate in a stepped-frequency mode at 5-GHz for all linear polarization combinations. This new radar will be used to sense vegetation dynamics of crops. In addition to C-band radar, the recently developed 4-channel VHF receiver hardware will be integrated with the hydraulic boom truck to perform measurements of direct and reflected signals in the 240-270 MHz VHF/UHF band from MilSatCom satellites utilizing sky- and Earth-looking antennas. This will add a new capability to the existing system to penetrate denser vegetation and to respond to conditions deeper in the soil because of the use of a longer wavelength (VHF/UHF vs. L band)

## 3. FIELD EXPERIMENT

An extensive field campaign measuring winter wheat is planned to start in early spring 2016, continuing through harvest near the heavily instrumented USDA-ARS (U.S. Dept. of Agriculture- Agricultural Research Service) OPE3 (Optimizing Production Inputs for Economic and Environmental Enhancement) test site in Beltsville, MD. The data will be acquired to address multi-frequency active/passive microwave algorithm needs for accurate soil moisture retrieval and vegetation characterization. ComRAD microwave measurements will be made at the SMAP incidence angle of 40°, autonomously every 90 minutes (weather permitting) accordingly. Various in situ sensors such as soil moisture, soil temperature, and leaf wetness sensors will be installed by USDA to provide continuous ground truth data. These data will be supplemented by additional soil moisture data collected manually twice a week by USDA personnel, along with weekly plant architectural, water content, and density measurements. The OPE3 site also contains a SCAN meteorological station and a flux tower which record precipitation and other micrometeorological data.

## 4. REFERENCES

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[3] GNSS P-band root-zone soil moisture reference needed!